where P_{90° is the intensity of the net normal pressure, P is the aerostatical pressure, V is the velocity in meters per second, and T and T_0 are absolute temperatures.

This formula does not rest on a sound basis, for it may be derived from that given by Lord Rayleigh, by expanding and rejecting the higher powers of $\dfrac{V}{a}$ than the square

$$P_{90^\circ} = P \left\{ \left(1 + \frac{r-1}{2} \frac{V^2}{a^2}\right)^{\frac{r}{r-1}} - 1 \right\}$$

for the resistance that would be encountered if the impinging filament of fluid could be supposed to disappear absolutely, after imparting all of its momentum to the plate; (r is here equal to the ratio of the specific heats of the gas at constant pressure and at constant volume, and a is the velocity of sound in the gas).

E. Toepler[12] in 1887 proposed a formula based on considerations derived from the molecular theory of gases:

$$P_{90^\circ} = 4\, P \frac{V}{\Omega},$$

where, as before, P is the aerostatical pressure, V the velocity of the plate, and Ω the mean molecular velocity of the particles of the gas. Experiments made by G. A. Hirn, in 1882, appear, however, to disprove any such immediate dependence of the resistance on the temperature as is here implied, when the density remains constant.

Ch. de Louvrié's formula (1890),

$$P_a = \frac{2 \sin \alpha\, (1 + \cos \alpha)}{1 + \cos \alpha + \sin \alpha} P_{90^\circ}$$

is quite satisfactory. The basis for the physical considerations on which this rational formula is founded may be discovered in Colonel Duchemin's experiments.

The latest addition to this collection of formulas, that of Lord Kelvin (1894), requires a word of explanation.

The resistance experienced by a moving solid in a "perfect" or frictionless fluid would be zero, if no surface of discontinuity were formed, or if the fluid obeyed the so-called "electrical law" of flow, requiring under certain conditions an infinite tension to be resisted. The kinetic energy of the body would, however, be changed by the presence of the fluid, and the additional kinetic energy is found to be

$$T = \frac{\pi \rho\, a^2 v^2}{2}$$

per unit of length of an infinitely long lamina of breadth a; or

$$T = \tfrac{4}{3} \rho\, c^3\, v^3$$

for a circular plate of radius c, ρ in both cases being the specific mass of the fluid, and v the velocity in a direction normal to the plate.[13]

These results were obtained by supposing the minor axis of an elliptical cylinder, and the shorter axis of a prolate spheroid, respectively, to become equal to zero. The motion of the fluid is in both cases irrotational, and therefore in the first case, for an infinitely long lamina, it could have been generated by an impulsive pressure of

$$F = \frac{\pi}{4} \rho\, a^2 v$$

per unit length. From this value of the impulsive pressure and from the assumption of a velocity in its own plane of u, that is large compared with v, Lord Kelvin found the resistance to be

$$P_a = \frac{\pi}{2} \rho\, u\, v$$

which is equivalent to

P_a is proportional to $\sin \alpha \cos \alpha\ V^2$

[12] Wiedemann's "Beiblätter" Vol. XI, 1887, p. 747.   [13] Lamb, op. cit.

for α small, and the length great compared to the breadth in the direction of motion.

A brief account of the most notable series of experiments since 1870 must close this summary.

The measurements of G. H. L. Hagen (1874) have become classic; they may be exprest by

$$P_{90^\circ} = (0.00707 + 0.0001125\, p)\ V^2,$$

where P_{90° is the intensity of normal pressure in grams per square decimeter, V is the velocity in decimeters per second, and p is the perimeter in decimeters. Unfortunately this formula can not be safely applied to plates of more than 20 centimeters on a side.

L. de Saint Loup (1879), for a plate 10 by 20 centimeters, found

$$P_a = 0.1768\, (4 \sin \alpha - 1)\, (11\ V + 1.061\ V^2)$$

where P is the pressure in grams per square decimeter, and V is the velocity in meters per second.

From the above-mentioned experiments of G. A. Hirn, in 1882, and from the carefully executed tests of Messrs. Cailletet and Colardeau in 1893, it appears definitely settled that, even for different gases, *the resistance is not directly affected by the temperature, but only indirectly thru the resulting change of density, and that this resistance is directly proportional to the density of the gas and to the square of the velocity of the vane.*

Otto Lilienthal, in 1889, experimented on the resistance of curved vanes, but without arriving at a satisfactory general formula.

Lieutenant Crosby in 1890 published an account of a series of experiments purporting to show that the resistance of the air was directly proportional to the velocity instead of to its square, but these experiments are not viewed with much favor.

Mr. W. H. Dines' extensive tests, also in 1890, on small plates exposed both normally and at an angle to the wind, give

$$P_{90^\circ} = 0.0029\ V^2$$

where P_{90° is the pressure in pounds per square foot, and V is the velocity in miles per hour; the measurements with the plate exposed obliquely have not been embodied in a formula.

This list is fittingly closed by a mention of Mr. S. P. Langley's very satisfactory experiments, published in 1891. His most refined apparatus gave, as the probable value of the normal pressure P_{90° on a plate exposed at right-angles to the direction of the wind, on planes of from 6 to 12 inches on a side

$$P_{90^\circ} = 0.0087\, \frac{\delta}{\delta_0}\ V^2,$$

where P_{90° is the pressure in grams per square centimeter, V is the velocity in meters per second, δ is the specific weight of the air at the time of the experiment, and δ_0 is that for a pressure of 760 millimeters mercury and at a temperature of 10° centigrade. Mr. Langley's experiments on planes exposed at an angle to the current of air agree so nearly with Colonel Duchemin's formula,

$$P_a = \frac{2 \sin \alpha}{1 + \sin^2 \alpha} P_{90^\circ},$$

that no new one is offered.

LOCAL FORECASTING AT ESCANABA.

By W. P. STEWART, Observer, Weather Bureau. Dated Escanaba, Mich., August 31, 1907.

Aside from, or rather superimposed upon, the more or less regular sequence of weather changes due to passing cyclones and anticyclones, most localities have a system of minor variations caused by local peculiarities of topography or location with regard to neighboring bodies of water, etc. In some cases these minor variations become so pronounced as greatly to modify the current weather of the region. Probably in no portion of the United States is this more noticeable than in the upper Lake region. The water of the Lakes, relatively

cool in the spring and summer and relatively warm n the fall and winter, is the dominating factor in determining the weather of this region.

At Escanaba, Mich., on account of its location on the western shore of Little Bay de Noc, an arm extending northward from the northern end of Green Bay, the weather is greatly modified by local influences. Daily temperature changes during the spring, summer, and fall are dependent largely upon the direction of the wind with regard to the waters of the bay. The temperature of Green Bay, owing to its landlocked position, rises very slowly in spring. For this reason, except in extreme cases, cool weather may be forecast with safety from April to September whenever it is expected that the wind will shift to the south or southeast, or warmer when the wind is expected to shift to the southwest or west. So pronounced is this effect that in the case of a rapidly shifting wind the rise and fall of temperature are often too rapid for the thermograph to follow, sometimes amounting to 10° or 15° in as many minutes. During the seasons mentioned the warmest days at Escanaba come with a southwest or west wind, when a barometric depression is moving eastward over Lake Superior, and the highest temperature occurs when the low is central toward the eastern end of the lake. This, evidently, is simply a case of warmer air coming from off the land, and if it accompany a rapidly moving disturbance the warm weather will be of brief duration, a sharp fall in temperature occurring when the wind shifts to northwest.

In forecasting for this region it should be borne in mind that barometric depressions will usually decrease in energy as they approach the Lakes during the spring and early summer and increase during the fall and winter, the apparent reason being that convectional action is less energetic over the relatively cool waters in the former season and greater over the relatively warm waters in the latter.

During the spring and early summer it is unsafe to forecast precipitation from an approaching low so long as the wind is expected to come from Green Bay; the obvious reason is that as the air passes from the water to the land its temperature rises, which increases its capacity for the vapor of water. During the season mentioned it is also unsafe to forecast thunderstorms with a southeast or south wind, except in pronounced cases. Thunderstorms often may be seen approaching from the west when the wind is from the southeast or south, but when almost overhead, and when thunder is momentarily expected, they begin to dissolve, and soon only a few strato-cumulus clouds are left. Thunderstorms require for their continued action an abundance of warm, moist air near the ground. While the air from over Green Bay probably contains sufficient moisture, its initial temperature is too low to give it the necessary ascending movement. Late in the summer, when the waters of Green Bay become warmer, this effect is less noticeable.

During the fall, winter, and spring, when a high is in the St. Lawrence Valley, and a low is approaching from the west, the sequence of changes attending the passage of a cyclone should be forecast only with extreme caution. Under these conditions the low may remain nearly stationary for two or three days, or it may even move westward. From Bowie's method of determining the probable movement of a depression this is what should be expected; and if it be remembered that the high appears to have difficulty in getting out of the St. Lawrence Valley, and is itself likely to remain practically stationary for forty-eight hours, this method may be used in these cases with a high degree of success.

Cold waves should be forecast for Escanaba only under exceptional conditions. Owing, probably, to the protection afforded by Lake Superior, cold waves are felt much more severely both to the eastward and to the westward than at Escanaba. A cold wave approaching from the northwest, which would appear likely to pass directly over this station, will usually be diverted to the westward, and extremely cold weather will arrive about twenty-four hours late, that is, when the crest of the high is well down the Mississippi Valley and the wind has backed to the southwest. In these cases it is usually 10° colder at Green Bay than at Escanaba. Another class of cold waves, coming apparently from Hudson Bay, passes southward over the eastern end of Lake Superior. The cold from these highs comes very quickly, but the temperature is usually 15° to 20° lower at Sault Sainte Marie than at Escanaba.

LIGHTNING PHENOMENA.
By Dr. IRVING LANGMUIR. Dated Stevens Institute, Hoboken, N. J., September 11, 1907.

I have read with interest an account of a peculiar phenomenon in connection with a flash of lightning, on page 228 of the May, 1907, number of the MONTHLY WEATHER REVIEW.

I have also seen such phenomena and would like to bear testimony to their occurrence on not very rare occasions, at least in the mountains of Switzerland. I remember three storms I have witnessed at different times in which flashes of lightning left their paths distinctly marked by strings of fire beads. Two of these storms were in the Alps, one at Berchtesgaden in southern Germany, and one on the mountain near Lake Lucerne, in Switzerland. The third was at Jackson, N. H., in the White Mountains. Each of these three storms was exceptionally violent, among the most violent I have ever witnessed. The phenomenon was observed only with flashes which were comparatively close, within perhaps 2000 feet. In each storm several flashes left beaded trails, but not every flash which struck near by exhibited that peculiar appearance.

I should estimate the time during which the beads remained visible as at least one second, a time amply sufficient to observe distinctly. It appeared to me that the whole course of the flash remained luminous, with a dull red glow, but that at intervals along the path bright points like sparks appeared to remain suspended in the air. The sparks appeared to be moving horizontally as tho blown along by the wind.

I have spoken many times with others about the phenomenon, but have met no one, even among experienced mountaineers, who had observed anything like it. I had, therefore, begun to suspect that the phenomenon was of a subjective nature, that is, was due to some peculiar impression left upon the retina of the eye by the brilliant discharge. The appearance of the sparks drifting along with the wind is strong evidence against this theory.

SALTON SEA AND LOCAL CLIMATE.

An editorial in the New York Daily Tribune of March 4, 1907, suggests that the Weather Bureau should have at hand data to decide whether the formation and presence of the Salton Sea has an appreciable influence on local climate. Now, without waiting for special local observations of temperature or moisture, we can easily demonstrate the slight influence of this sea on the general climate, especially on the rainfall.

The Salton Sea has an estimated area of 400 hundred square miles and an average depth of less than 80 feet. The total volume of water may be 400 by $(5280)^2$ by 70 cubic feet,[1] equivalent to a depth of 28,000 feet over 1 square mile, or 1 foot over 28,000 square miles, or about 2 inches over the 158,000 square miles of California, and is much less than falls in almost any one area of low pressure during the few days of its progress over the United States. This amount of water would suffice to provide for the irrigation of the whole 300 square miles of the Imperial Valley for forty or fifty years, if that region required only 20 inches in depth per annum. Therefore the practical question is not how much the Salton Sea can affect climate, but how its waters can be used for irrigating the lands that surround it.—C. A.

[1] As estimated by Mr. A. P. Davis. See his paper in the National Geographic Magazine, January, 1907.